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Heat of Imbibition by Seeds.

By George Macloskie.

The explanation of the production of heat in germinating seeds by destructive metabolism, with the production of carbon dioxide, is only part of the case; and fails at the initial step, where the necessity is greatest. Nor will it suffice to supplement our explanation by suggestions of rising temperature of the atmosphere or of the soil; for in some cases germination has occurred at low temperatures, even at the freezing point of the soil.

A supplementary, or rather a preliminary source of warmth may be found in the discovery by botanists of a physical law, which though not much discussed by either botanists or physicists, seems to have large application to problems that meet us in all branches of investigation. Sachs informs us * that heat is set free when water enters into organized, and, to a smaller extent, unorganized bodies; stating that according to Pfeffer this was first established by Pouillet, and that in 1865 it was confirmed by Jungk and himself. Nägeli's experiment on this consisted of drying flour-starch, so as to deprive it as far as possible of all water, and then immersing some of it in an equal weight of distilled water, which resulted in a rise of 11.6° C. †

Sachs applies to this result Joule's estimate that 0.03° C. indicates a pressure equal to 34.3 atmospheres; hence 11.6° C. will represent many hundreds of atmospheres. (In fact it would represent more than 13,000 atmospheric pressures, an almost incredible estimate.) This calculation enters into Sachs' theory of the ascent of water in stems of trees, because of the high pressure with which it forces its way into fine tissues like the wood-cells: and which he further illustrates by reference to the use of wedges of wood for splitting granite, on the application of water so as to swell them. He accounts for the phenomenon by supposing that

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* Lectures on the Physiology of Plants, translated by Vines, 210.

† Theorie der Gärung. Abhand. der Akad. Wissensch. München, 13: 187. 1879.

the water has became compressed within the starch, and suggests that the water first entering the starch undergoes the highest rise of temperature, and therefore the greatest compression. Perhaps the phenomenon is parallel with that of gases entering spongy platinum or charcoal ; and there may be partial condensation as well as compression of the imbibed water. Ganot states that the 'humus' is warmed in moist air by the imbibition of vapor, and that plants are thereby benefited. (Ganot's *Physics*, § 482.)

Neither Sachs, nor any other of the physiologists, so far as we know, has applied this discovery to the case of germination. The comparative freedom from water of ripe seeds has been usually explained as a protection from injury by exposure to extremes of heat or cold, but it seems to be also in a certain way a reserve of potential energy to be drawn on at proper time.

In a rude experiment we placed dry peas with water in a bottle, and beside it a 'controul' bottle of water at the same starting temperature. In about an hour the temperature of the first bottle exceeded that of the second; soon the difference reached 1° C., at which it remained for three days, when some of the peas were germinating. In a second experiment we used dry split-peas, devoid of seed-coat, without radicle or plumule, where there could be no germination. They absorbed the water quickly, but, as there was much loss of heat by radiation, they kept at a temperature only 1° C. higher than that of the control bottle; thus for fifteen hours, when they had become saturated, and the temperature fell to that of the other bottle. The difference of 1° C. will not appear insignificant if we reflect that Sachs made out a difference of only 1.5° C. between the temperature of germinating peas and that of the surrounding air. We may expect that the temperature after germination, though produced in a different way, is continuous in amount with the temperature before germination caused by the imbibition of water, and that there is no jolt or gap as to warmth in the transition from the dormant to the active condition of the embryo.

We have not attempted a quantitative estimate of the amount of heat produced. This might be effected by taking the weight of the seeds and the weight of the water, and finding how much ice would be necessary to keep them down to the temperature of the control bottle during the entire course of imbibition until germination begins. The significant part of the process is that when seeds are well protected from loss of heat, the imbibition-heat becomes cumulative, so as to reach a considerable amount and to be effective in starting the radicle of the young plant. This may help to elucidate the case cited by Uloth (1871) of the germination of seeds in ice. He found seeds of *Acer platanoides* and also of wheat, between blocks of ice in an ice-house, having started to grow and having pushed their roots several inches down into the fissureless ice. His suggestion was that heat may have radiated through the ice. It appears more probable that something like a lighted taper or burning straw may have melted enough of the ice to wet the seeds, that the heat of imbibition thus produced might melt more of the ice, and this cumulatingly react upon the seed, and so on acting and reacting, whilst the ice itself would present an obstacle against the waste of heat by dissipation in other directions. The fact of its not being an isolated case of a single seed is evidence to prove that there must have been some general cause at work.

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